SYSTEM AND METHOD FOR SCHEDULING TRANSMISSIONS IN A WIRELESS COMMUNICATION SYSTEM

Claim of Priority under 35 U.S.C. §119

[0001] The present Application for Patent claims priority to Provisional Application No. 60/448,269 entitled "Reverse Link Data Communication" filed February 18, 2003, and Provisional Application No. 60/470,225 entitled "Method and Apparatus for Quality of Service in IS-2000 Reverse Link" filed May 12, 2003, and assigned to the assignee hereof and hereby expressly incorporated by reference herein.

BACKGROUND

Field

[0002] The invention relates generally to the field of telecommunications, and more particularly to systems and methods for scheduling data transmissions in a wireless communication system using scheduling requests and grants.

Background

[0003] Wireless communication technologies are rapidly advancing, and wireless communication systems are utilized to provide a larger and larger portion of the communications capacity that is currently available to users. This is true despite the additional technological impediments that are faced in implementing a wireless communication system, as compared to a wireline system. For instance, wireless communication systems must deal with issues relating to transmission scheduling between a base station and its mobile stations when the quality of the wireless communication channels between them is constantly changing. The base station and mobile stations must therefore deal with the issue of how much data can be transmitted in light of the prevailing conditions rather than simply scheduling transmissions, as in a wireline system.

[0004] One type of wireless communication system comprises a cellular CDMA (code division multiple access) system which is configured to support voice and data communications. This system may have multiple base stations which communicate via wireless channels with multiple mobile stations. (The base stations are also typically coupled via wireline networks to various other systems, such as a base switching station

that may couple the base stations to the internet or a public switched telephone network.)

[0005] As mobile stations move through the area covered by the wireless communication system, they may communicate with multiple base stations. The mobile stations may also be handed off from one base station to another. This is referred to as a handoff between the base stations. Conventionally, because the mobile stations are handed off from one base station to another, the scheduling of transmissions, particularly transmissions from the mobile stations to the base stations, is handled by the base station controller, which is coupled to the base stations and can therefore account for the handoffs of the mobile stations.

[0006] While the transmissions are conventionally scheduled by the base station controller, this does cause some delay in the scheduling. This delay is a result of the fact that the information relevant to scheduling (e.g., a request message) is carried in Layer 3 messages that are first obtained by the base stations, and then transmitted to the base station controller, which makes appropriate scheduling decisions and then transmits the resulting scheduling information back to the base stations. Adding to this delay is the fact that Layer 3 messages have to be processed by the LAC layer (which is above the MAC layer, but below Layer 3). Also, Layer 3 messages are commonly processed by a shared CPU, rather than a dedicated CPU, although this varies from implementation to implementation. Further contributing to the delay is the propagation delay between the base station and base station controller, where Layer 3 messages are commonly processed. . There is therefore a need in the art for systems and methods that perform scheduling of data transmissions without incurring the delays experienced in the prior art.

SUMMARY

[0007] Embodiments of the invention which are disclosed herein address one or more of the needs indicated above by performing at east a portion of the data transmission scheduling at the base station rather than the base station controller.

[0008] In one embodiment, a wireless communication system having a base station and one or more mobile stations provides, between the base station and each mobile station, a forward link for communicating information from the base station to the mobile station, and a reverse link for communicating information from the mobile station to the

base station. The system is configured to allocate reverse link resources using a request-grant mechanism. According to this mechanism, the mobile station accumulates data in one or more buffers. Each buffer stores data for a particular class of service. When the amount of data in one of the buffers reaches a threshold, the mobile station generates a request message and transmits this message to the base station. The base station receives the request message, as well as request messages from other mobile stations, and processes the requests to determine an allocation of the available reverse link resources. Based on this allocation, the base station may transmit one or more grant messages to the mobile stations, granting the mobile stations permission to transmit data for specified classes of service. The mobile stations then transmit their data to the base station as authorized by the grant messages. If a mobile station did not receive a grant to transmit data, the mobile station may transmit the data autonomously at a predetermined rate, which is typically lower than the rates at which transmission under a grant can proceed.

[0009] One embodiment of the invention comprises a base station having a transceiver subsystem and a processing subsystem, where the processing subsystem is configured to receive a request for service from a mobile station and to make a determination whether or not to issue a grant to transmit data (a "grant") to the mobile station in response to the request for grant. The processing of the request occurs in the base station at the medium access control layer. The base station may issue an individual grant or a common grant responsive to the request. Alternatively, no grant may be issued at all. The request identifies a particular class of service. The grant can specify the granted traffic to pilot ratio for multiple classes of service if it is a common grant, but not if the grant is an individual grant.

[0010] One embodiment of the invention comprises a mobile station having a transceiver subsystem and a processing subsystem coupled to the transceiver subsystem, where the processing subsystem is configured to process information received from the transceiver subsystem and to generate information to be transmitted by the transceiver subsystem. In particular, the processing subsystem is configured to generate a request for transmission to a base station, to identify a corresponding grant received from the base station, and to control the transceiver subsystem to transmit data according to the received grant. The request specifies one of a set of available classes of service. A grant may also specify a particular class of service (a common grant specifies a class of

service, but an individual grant does not). When a grant is received, the mobile station transmits data corresponding to the traffic to pilot ratio identified by the grant.

[0011] One embodiment of the invention is a wireless communication system having a base station and one or more mobile stations configured to communicate with the base station via corresponding wireless communication links. Each mobile station is configured to transmit requests for grants to the base station. The base station is configured to receive requests from the mobile stations, to process the requests independently of a base station controller, to allocate communication link resources among the mobile stations, and, if necessary, to transmit one or more grants to the mobile stations in accordance with the allocation of communication link resources. Each mobile station is configured to transmit data to the base station in accordance with any grants received from the base station.

[0012] One embodiment of the invention comprises a method which includes the steps of receiving a request for a grant at a base station, processing the request at the base station and determining at the base station whether to issue the grant. The processing of the request occurs in the base station at the medium access control layer. The base station may issue an individual grant or a common grant responsive to the request. Alternatively, no grant may be issued at all.

[0013] One embodiment of the invention comprises a method which includes the steps of transmitting a request for a grant from a mobile station, wherein the request specifies one of a set of available classes of service, if a grant corresponding to the request is issued, transmitting data according to the received grant, and if no grant corresponding to the request is issued, transmitting data in an autonomous mode or transmitting a subsequent request, or both.

[0014] Numerous additional embodiments are also possible.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Various aspects and features of the invention are disclosed by the following detailed description and the references to the accompanying drawings, wherein:

[0016] FIGURE 1 is a diagram illustrating the structure of an exemplary wireless communications system in accordance with one embodiment;

[0017] FIGURE 2 is a functional block diagram illustrating the basic structural components of a wireless transceiver system in accordance with one embodiment;

[0018] FIGURE 3 is a diagram illustrating multiple channels between the mobile station and base station in accordance with one embodiment; and

[0019] FIGURE 4 is a flow diagram illustrating the communication of requests and grants between a mobile station and a base station in accordance with one embodiment.

[0020] While the invention is subject to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and the accompanying detailed description. It should be understood, however, that the drawings and detailed description are not intended to limit the invention to the particular embodiments which are described.

DETAILED DESCRIPTION

[0021] One or more embodiments of the invention are described below. It should be noted that these and any other embodiments described below are exemplary and are intended to be illustrative of the invention rather than limiting.

[0022] As described herein, various embodiments of the invention comprise systems and methods for scheduling data transmissions in a wireless communication system using scheduling requests and grants.

[0023] In one embodiment, a wireless communication system having a base station and one or more mobile stations provides, between the base station and each mobile station, a forward link for communicating information from the base station to the mobile station, and a reverse link for communicating information from the mobile station to the base station. The mobile station may communicate different types of information to the base station. For example, the mobile station may communicate voice, data or multimedia information to the base station. The mobile station may have different Quality of Service (QoS) requirements for each of these different types of information. For example, voice information must be transmitted in real time in order to avoid audible artifacts of delayed delivery of the information. Non-voice information, on the other hand, may require a higher overall data rate, but may be able to tolerate delays that would be unacceptable for voice information. Embodiments of the present invention therefore provide means to associate different QoS levels with different types of data so that the corresponding QoS requirements can be met.

[0024] In one embodiment, each mobile station may transmit data autonomously to the serving base station at a rate no higher than a predetermined rate, such as 19.2 kbps for

the initial transmission (after a hybrid automatic repeat, the actual effective rate drops to about half this rate). If a higher transmission rate is needed, the mobile station transmits a request for a grant to the base station. The request identifies the mobile station, a class of service for the data to be transmitted, the amount of data that needs to be transmitted, and a maximum supportable traffic-to-pilot (T/P) ratio. The mobile station may transmit a separate request corresponding to each of a set of service classes. The base station receives the requests for grant from the mobile station and determines an allocation of resources for this and any requests that are received from other mobile stations served by the base station. Based on the allocation determined by the base station, the base station may transmit a grant responsive to each request. to the corresponding mobile stations. If the base station determines that no resources are to be allocated to a particular mobile station given the available information about class of service, no grant is transmitted. The grants specify the corresponding mobile stations, and maximum T/P ratios (for the corresponding class of service in case of a common grant). The mobile stations which receive these grants can then transmit their data according to the appropriate grant parameters.

[0025] One of the benefits provided by this system is that the base station does not simply forward the mobile stations' requests to a base station controller, as in the prior art, but instead processes the requests, makes resource allocation determinations, and transmits grants to the mobile stations according to the resource allocation. The base station thereby eliminates the delays that result from the need in prior art systems to transmit the mobile station requests from the base station to the base station controller and to return scheduling information from the base station controller to the base station. In one embodiment, the system may also realize benefits from making common grants to the mobile stations, as well as individual grants. The common grants may specify particular classes of service, and any mobile station may transmit data under a common grant, as long as the data is associated with the class of service identified in the common grant. Various other benefits may be provided as described in more detail below in relation to the preferred embodiments.

[0026] A preferred embodiment of the invention is implemented in a wireless communication system that conforms generally to a release of the cdma2000 specification. cdma2000 is a 3rd Generation (3G) wireless communication standard that is based on the IS-95 standard. The cdma2000 standard has evolved and continues to

evolve to continually support new services in a standard 1.25 MHz carrier. The preferred embodiment of the invention is intended to be operable in systems utilizing Release D of the cdma2000 standard, but other embodiments may be implemented in other Releases of cdma2000 or in systems that conform to other standards (e.g., W-CDMA). The embodiments described herein should therefore be considered exemplary, rather than limiting.

[0027] Referring to FIGURE 1, a diagram illustrating the structure of an exemplary wireless communications system is shown. As depicted in this figure, system 100 comprises a base station 110 that is configured to communicate with a plurality of mobile stations 120. Mobile stations 120 may, for example, be cellular telephones, personal information managers (PIMs or PDA), or the like that are configured for wireless communication. It should be noted that these devices need not actually be "mobile," but may simply communicate with base station 110 via a wireless link. Base station 110 transmits data to mobile stations 120 via corresponding forward link (FL) channels, while mobile stations 120 transmit data to base station 110 via corresponding reverse link (RL) channels.

[0028] It should be noted that, for the purposes of this disclosure, identical items in the figures may be indicated by identical reference numerals followed by a lowercase letter, e.g., 120a, 120b, and so on. The items may be collectively referred to herein simply by the reference numeral.

[0029] Base station 110 is also coupled to a base station controller 130 via a network 160. base station controller 130 is connected to a number of additional base stations (not shown) through network 160, forming a wireless communication system. Base station 110 may also be connected to various other system components, such as data servers, a public switched telephone network, the Internet, and the like through network 160. While the base station controller conventionally controls the scheduling of transmissions for the base stations in the system, at least a portion of the scheduling responsibilities in the present system are moved to base station 110.

[0030] It should be noted that the mobile stations and system components in this figure are exemplary and other systems may comprise other combinations of devices and may have different topologies than the specific configuration depicted in FIGURE 1.

[0031] While, in practice, the specific designs of base station 110 and mobile stations 120 may vary significantly, each serves as a wireless transceiver for communicating

over the forward and reverse links. Base station 110 and mobile stations 120 therefore have the same general structure. This structure is illustrated in FIGURE 2.

[0032] Referring to FIGURE 2, a functional block diagram illustrating the basic structural components of a wireless transceiver system in accordance with one embodiment is shown. As depicted in this figure, the system comprises a transmit subsystem 222 and a receive subsystem 224, each of which is coupled to an antenna 226. Transmit subsystem 222 and receive subsystem 224 may be collectively referred to as a transceiver subsystem. Transmit subsystem 222 and receive subsystem 224 access the forward and reverse links through antenna 226. Transmit subsystem 222 and receive subsystem 224 are also coupled to processor 228, which is configured to control transmit and receive subsystems 222 and 224. Memory 230 is coupled to processor 228 to provide working space and local storage for the processor. A data source 232 is coupled to processor 228 to provide data for transmission by the system. Data source 232 may, for example, comprise a microphone or an input from a network device. The data is processed by processor 228 and then forwarded to transmit subsystem 222, which transmits the data via antenna 226. Data received by receive subsystem 224 through antenna 226 is forwarded to processor 228 for processing and then to data output 234 for presentation to a user. Data output 234 may comprise such devices as a speaker, a visual display, or an output to a network device.

[0033] Persons of skill in the art of the invention will appreciate that the structure depicted in FIGURE 2 is illustrative and that other embodiments may use alternative configurations. For example, processor 350, which may be a general-purpose microprocessor, a digital signal processor (DSP) or a special-purpose processor, may perform some or all of the functions of other components of the transceiver, or any other processing required by the transceiver. The scope of the claims appended hereto are therefore not limited to the particular configurations described herein.

[0034] Considering the structure of FIGURE 2 as implemented in a mobile station, the components of the system can be viewed as a transceiver subsystem coupled to a processing subsystem, where the transceiver subsystem is responsible for receiving and transmitting data over wireless channel and the processing subsystem is responsible for preparing and providing data to the transceiver subsystem for transmission and receiving and processing data that it gets from the transceiver subsystem. The transceiver subsystem could be considered to include transmit subsystem 222, receive

subsystem 224 and antenna 226. The processing subsystem could be considered to include processor 228, memory 230, data source 232 and data output 234.

[0035] As indicated above, the communication link between the base station and the mobile station actually comprises various channels. Referring to FIGURE 3, a diagram illustrating multiple channels between the mobile station and base station is shown. As depicted in the figure, Base station 110 transmits data to mobile station 120 via a set of forward link channels 310. These channels typically include both traffic channels, over which data is transmitted, and control channels, over which control signals are transmitted. Each of the traffic channels generally has one or more control channels associated with it. Forward link channels 310 may include, for example, a Forward Fundamental Channel (F-FCH) that may be used to transmit low-speed data, a Forward Supplemental Channel (F-SCH) that may be used for high-speed, point-to-point communications, or a Forward Packet Data Channel (F-PDCH) that may be used to broadcast messages to multiple recipients. The channels may also include a Forward Dedicated Control Channel (F-DCCH), a forward broadcast control channel (F-BCCH) or a Forward Paging Channel (F-PCH) that may be used to transmit control information relating to the traffic channels or to other aspects of the operation of the system.

[0036] Mobile station 120 transmits data to base station 110 via a set of reverse link channels 320. Again, these channels typically include both traffic channels and control channels. Mobile station 120 may transmit control information back to the base station over such channels as a reverse access channel (R-ACH), an extended reverse access channel (R-EACH), a reverse request channel (R-REQCH), a reverse dedicated control channel (R-DCCH), a reverse common control channel (R-CCCH), or a reverse rate indicator channel (R-RICH). The mobile station may transmit data via channels such as a reverse packet data channel (R-PDCH).

[0037] In many instances, reverse link capacity is interference limited. Base stations allocate available reverse link communication resources to mobile stations for efficient utilization to maximize throughput in accordance with Quality of Service (QoS) requirements for the various mobile stations.

[0038] Maximizing the use of the reverse link communication resources involves several factors. One factor to consider is the mix of scheduled reverse link transmissions from the different mobile stations, each of which may be experiencing varying channel quality at any given time. To increase overall throughput (the

aggregate data transmitted by all the mobile stations in the cell), it is desirable for the entire reverse link to be fully utilized whenever there is reverse link data to be sent. To fill the available capacity, some mobile stations may be granted access at the highest rate they can support. Additional mobile stations may be granted access until capacity is reached. In deciding which mobile stations to schedule, the base station may therefore consider the maximum rate each mobile station can support and the amount of data each mobile station has to transmit. A mobile station capable of higher throughput (considering both the data rate supportable by the mobile station and the amount of data the mobile station has to transmit) may be selected instead of an alternate mobile station that cannot currently support the higher throughput.

[0039] Another factor to be considered is the quality of service required by each mobile station. It may be permissible to delay access to a particular mobile station in hopes that the mobile station's channel (or more specifically its supportable throughput) will improve, instead selecting mobile station that can support higher throughput. It may be the case, however, that a sub-optimal mobile station may need to be granted access in order to allow the mobile station to meet minimum quality of service guarantees. Therefore, the data throughput that is actually scheduled may not be the absolute maximum, but may instead be optimized in light of channel conditions, available mobile station transmit power, quality of service requirements, and similar factors.

[0040] Various scheduling mechanisms may be used to allow a mobile station to transmit data on the reverse link. One class of reverse link transmissions involves the mobile station making a request to transmit on the reverse link. The base station makes a determination of whether resources are available to accommodate the request, and a grant can be made by the base station to allow the transmission. The grant be made specifically to an individual mobile station, or it may be a common grant to all of the mobile stations. A common grant is broadcast to all of the mobile stations, although it may not be decoded by all of the mobile stations. Alternatively, the mobile station may not have sufficient data or channel quality to justify a request, and may autonomously transmit data to the base station.

[0041] The base station allocates the capacity of the reverse link to one or more mobile stations. A mobile station that is granted access is allowed a maximum power level or data rate for the transmissions that will be made under the grant. In one embodiment, the reverse link capacity is allocated using a T/P ratio. Since the pilot signal of each

mobile station is adaptively controlled by a power control, specifying the T/P ratio indicates the available power for use in transmitting data on the reverse link. A corresponding data rate can be determined from the T/P ratio.

[0042] Referring to FIGURE 4, a diagram illustrating a method of transmitting requests and corresponding grants in accordance with one embodiment is shown. As depicted in FIGURE 4, reverse-link requests are first transmitted from the mobile station to the base station. Each request identifies the mobile station making the request, and also identifies a maximum supportable T/P ratio, the particular class of service for which the grant is requested, and the size of the queue corresponding to the identified class of service. In this embodiment, the class of service is identified by a service reference identifier (SR_ID) in a QoS control field of the request. The service reference identifier consists of three bits and a reserve bit that identify up to six data services, plus Layer 3 signaling. The classes are assigned for the mobile station at call setup.

[0043] The mobile station may transmit multiple requests. In the particular situation depicted in FIGURE 4, the mobile station transmits two requests. One of the requests identifies service class SR_ID=1, while the other identifies service class SR_ID=2. This is necessary in this embodiment because requests are made on a per-mobile station, per-class basis. In other words, each mobile station must transmit a request to the base station for each class of service that has data to be transmitted. If the mobile station has data to be transmitted where the data was associated with a third class of service, a third request must be transmitted to the base station.

[0044] FIGURE 4 depicts only a single grant being transmitted from the base station to the mobile station. This may be the result of several different conditions. For example, if the base station does not receive one of the requests, it is not aware of the request and cannot issue a grant corresponding to that request. Another reason may be that the base station might have received both of the requests, but determined that reverse link resources should be allocated to only one of the requested classes of service. If the base station determines that reverse link resources should be allocated in response to a request, a grant will be transmitted to the mobile station in response to each of the requests. Then, if a request is granted, the mobile station will begin transmitting data under the grant.

[0045] As noted above, the forward and reverse links between the mobile station and the base station include a number of channels. These channels may include ones that

are intended to communicate specific types of control data and traffic. The channels may therefore include request channels, grant channels, traffic channels, acknowledgment channels, and the like. The specific channels may vary from one embodiment to another.

[0046] As noted above, the grants that are issued by the base station may be either individual grants, or common grants. In one embodiment, the base station receives requests from one or more of the mobile stations which it serves and performs some manner of processing on these requests in order to determine how the reverse link resources should be allocated. (Any of a variety of algorithms may be used in this determination, but these algorithms will not be described here, as they are not essential to the invention.) Based upon this processing, the base station may issue individual grants, common grants, or both. Alternatively, the base station may not issue any grants at all.

[0047] Each of the individual grants identifies a specific mobile station and a granted T/P ratio. Each common grant identifies granted T/P ratios for specific classes of service, but does not identify a particular mobile station. Any mobile station that has data in an identified class of service may transmit data under the common grant at the corresponding T/P ratio. As noted above, the base station may also determine that no grant at all should be issued with respect to certain mobile stations and/or classes of service. Thus, using this mechanism, the base station can give priority to higher classes of service, prevent transmission of data associated with selected classes, give priority to classes of service having more data to be transmitted, and so on.

[0048] It should be noted that, in this embodiment, the processing of the MAC layer messages received from the mobile stations is performed by the base station. This scheduling mechanism sharply contrasts with the prior art, in which the scheduling messages are Layer 3 messages that are normally processed by the base station controller. Thus, in a typical, conventional system, the base station does not make any scheduling decisions, but simply forwards information from the mobile stations to the base station controller so that the base station controller can make the scheduling decisions.

[0049] The processing of the MAC layer messages at the base station requires several changes from typical prior art systems. For instance, because the base station conventionally did not perform the scheduling/allocation of reverse link resources, base

stations conventionally had no logic for receiving and processing the requests from the mobile stations. It is therefore necessary to provide this logic, which typically is not found in conventional base stations. This logic may be implemented in hardware or software. Another difference between the present system and a conventional system is the fact that, because the base station processes information at the MAC layer (Layer 2) instead of Layer 3, the mobile stations must send scheduling messages (requests) as Layer 2 messages, rather than Layer 3 messages.

[0050] The processing of mobile stations' reverse link requests at the base station is somewhat unusual because it has conventionally been thought that the presence of multiple base stations and mobile stations in the system necessitated the use of the base station controller for scheduling in order to coordinate between the base stations. In the present system, however, it has been determined that this coordination is not necessary. This is because the power at which each mobile station transmits data is controlled so that errors are minimized, but not at the expense of wasting energy. In particular, the mobile station is controlled to use just enough power to achieve a minimum acceptable error rate. Typically, therefore, only one base station (the serving base station) will receive and correctly decode data from the mobile station. As a result, it is unnecessary to coordinate with other base stations, which most likely will not receive valid data from the mobile station.

[0051] In one embodiment, the request-grant process is event-driven. As the mobile station receives or generates data for a particular class of service, the data is stored in a buffer corresponding to that class of service. When the mobile station accumulates enough data in one of the buffers, the request is triggered. The frequency of requests is controlled in this embodiment by a signaling variable that specifies the minimum interval between two requests. The request identifies the class of service and the amount of data in the buffer (as well as the mobile station and the maximum supportable T/P ratio). The request is received by the base station, which decides whether or not to issue a grant responsive to the request. If a grant is issued, the mobile station begins transmitting data under the grant. If no grant is issued, the mobile station may transmit autonomously (typically at a much lower rate than under a grant), or it may transmit another request to the base station.

[0052] In one embodiment, once a mobile station begins transmitting under a grant, it may continue transmitting as long as the base station does not stop the transmissions.

More specifically, when a mobile station receives an individual grant, the grant is to transmit a single frame of data. When the frame is received by the base station, the base station transmits an acknowledgment (ACK) to the mobile station. The acknowledgment is either a positive acknowledgment or a negative acknowledgment. If the acknowledgment is positive, the mobile station transmits another frame of data to the base station. If the acknowledgment is negative, the mobile station does not transmit another frame of data, but may transmit another request if there is sufficient data in the corresponding buffer to justify the request.

[0053] If the mobile station is transmitting under a common grant instead of an individual grant, the mobile station may transmit data for a predetermined interval. This interval is specified by the common grant. If the mobile station still has sufficient data in the appropriate buffer, a new request is triggered and transmitted to the base station. Alternative embodiments may use an ACK-and-continue scheme, in which the transmission may continue as long as positive acknowledgements are received, as described above.

[0054] As indicated above, in an ACK-and-continue scheme, the mobile station may continue to transmit data under an individual grant as long as the mobile station continues to receive positive acknowledgments from the base station. In one embodiment, the mobile station is configured to provide feedback to the base station in regard to the transmission of the data frames subsequent to the first frame. This feedback may, for example, comprise updates to the maximum T/P ratio supportable by the mobile station. In one embodiment, the mechanism for providing this feedback could be similar to the mechanism used for power control, in that a very small number of bits could be periodically transmitted to the base station to indicate that the maximum supportable T/P ratio has increased or decreased. This feedback could be taken into account by the base station in determining whether to allow transmissions by the mobile station to continue or to terminate these transmissions. The base station could then send positive or negative acknowledgments, as appropriate.

[0055] Those of skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by

voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0056] Those of skill would further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

[0057] The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0058] One or more of the steps of the methods and/or algorithms described in connection with the embodiments disclosed herein may be interchanged without departing from the scope of the invention. The steps of the disclosed methods and/or algorithms may be embodied in hardware, in software modules executed by a processor, or in a combination of the two. Software modules may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read

information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a computer system. In the alternative, the processor and the storage medium may reside as discrete components in a computer system.

[0059] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is: